Effectiveness of woodland birds as taxonomic surrogates in conservation planning for biodiversity on farms

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Abstract

Woodland birds are a commonly used taxonomic surrogate for other species groups in agricultural landscapes as they are relatively diverse, easily-studied, and charismatic. Yet, other taxa can respond to native vegetation on farms differently to woodland birds, challenging the present focus on birds in agri-environmental schemes. We aimed to assess the effectiveness of woodland birds as taxonomic surrogates for biodiversity in conservation planning on farms, in comparison with reptiles and arboreal marsupials. We used a complementarity-based approach to select patches of remnant and restored vegetation that supported *a priori* representation targets of species occurrences. We found that the spatial locations of vegetation patches selected to meet representation targets for woodland birds were 24% - 69% different from the locations of patches selected for other taxa. The vegetation patches selected to meet representation targets for woodland birds failed to incidentally meet representation targets for other taxa, although targets for a subset of threatened woodland birds were exceeded. Conservation planning for woodland birds, however, led to higher incidental representation of the other taxa, compared with conservation planning for reptiles and arboreal marsupials. This indicates that woodland birds are a more effective taxonomic surrogate for biodiversity on farms compared to reptiles and arboreal marsupials. If the conservation goal is to conserve a broad array of biodiversity on farms, then the focus on woodland birds in agri-environmental schemes is justified. However, if the conservation of particular species or taxonomic groups is a priority, then conservation plans explicitly targeting these species or groups are required.

Keywords: Agricultural landscapes, Arboreal marsupials, Incidental representation, Marxan, Reptiles, Woodland birds

Highlights

- We compared woodland birds, reptiles, arboreal marsupials as taxonomic surrogates
- Conservation planning for any one taxon failed to incidentally represent other taxa
- Yet, woodland birds were more effective taxonomic surrogates than other taxa
- Threatened bird species were represented by woodland bird conservation plans
- Focus on woodland birds can conserve a broad array of biodiversity on farms

1. Introduction

A core challenge for conservation science is the lack of complete information on biodiversity, that is, a comprehensive inventory of all species of all groups in a given area (Williams and Gaston 1994). This challenge is difficult to address directly, given insufficient resources to survey the myriad of species in ecosystems, as well as the spatial and temporal complexity of ecosystem processes. Instead, surrogates for biodiversity are used, for instance environmental attributes or taxonomic groups, that attempt to represent the full assemblages of species to some degree (Howard et al. 1998; Andelman and Fagan 2000; Margules and Pressey 2000; Sarkar et al. 2006; Rodrigues and Brooks 2007).

Birds are the most commonly used taxonomic surrogate in terrestrial ecosystems (Eglington et al. 2012; Larsen et al. 2012; Westgate et al. 2014). They are a well-studied taxon, being highly detectable, easily identifiable, and inexpensive to survey compared with other vertebrate and invertebrate taxa. Their relatively high levels of species diversity, breadth of functional attributes, and heterogeneous distributions also contribute to their effectiveness in improving the efficiency of conservation planning and management (Lewandowski et al. 2010). Further, birds are a charismatic taxon garnering high public appeal, which makes them an ideal flagship group for conservation actions (Veríssimo et al. 2009).

In agricultural landscapes, birds are often the target group for agri-environmental initiatives (Guerrero et al. 2012), including restoration plantings and the protection of remnant vegetation. In Australia, most restoration initiatives aimed at improving biodiversity conservation (e.g. Lindenmayer et al. 2013) have focused on woodland birds. Woodland birds are defined here as species that occur in temperate woodland, not excluding species that also occur in grassland (Silcocks et al. 2005). There is a vast literature on woodland birds, exploring the importance of different vegetation attributes at patch and landscape scales (e.g. Watson et al. 2003; Radford et al. 2005; Barrett et al. 2008; Haslem and Bennett 2008; Bowen et al. 2009; Hanspach et al. 2011; Ikin et al. 2014), and in conservation planning (Thomson et al. 2009; Ikin et al. 2016). Findings from these studies contribute to the evidence-base for conserving a broad array of biodiversity on farms. However, other research shows that other groups of vertebrate taxa that are more difficult to survey, for example mammals and reptiles, can respond differently to vegetation composition and structure compared to woodland birds

(Cunningham et al. 2007; Jellinek et al. 2014; Michael et al. 2014; Yong et al. 2016). Such a discrepancy in responses to the landscape calls into question whether woodland birds are as good taxonomic surrogates for biodiversity on farms as they are supposed.

Our study aimed to assess the effectiveness of woodland birds as taxonomic surrogates in conservation planning for biodiversity on farms, in comparison with reptiles and arboreal marsupials. Agricultural landscapes, despite their highly modified state, can support high numbers of species (Yong et al. 2016), and systematic survey data on multiple taxonomic groups are rare (underscoring the necessity of using taxonomic surrogate approaches). We took advantage of the South West Slopes Restoration Study (Cunningham et al. 2007; Lindenmayer et al. 2016), which gathers detailed multi-taxon data across an extensive agricultural region of southeastern Australia. Using a complementarity-based approach, for each taxonomic group we identified patches of restored and remnant vegetation that together met *a priori* representation targets of species occurrence in the landscape. We asked:

1. Are the vegetation patches selected to meet representation targets for one taxon the same as vegetation patches selected for other taxa?
2. Which taxon achieved the best incidental representation of other taxa?

Given the relatively high species diversity and functional diversity of birds in the landscape, we predicted that a large number of restored and remnant vegetation patches would be needed to meet niche requirements (Moritz et al. 2001). Consequently, we expected that spatial concordance between these patches and those selected to meet representation targets for other taxa would be high, and therefore that conservation planning for woodland birds would be effective at incidentally representing other taxa – thus indicating that woodland birds are effective surrogates. However, we did not expect that the degree of spatial concordance or incidental representation would be identical between taxa (Lentini and Wintle 2015). For instance, we predicted that conservation planning for all woodland birds in our agricultural landscape would be: (i) less effective than conservation planning targeted at a subset of threatened woodland birds (Beger et al. 2003), and (ii) more effective at representing arboreal marsupials, which may use the landscape at similar scales to birds and thus may have similar ecological requirements, compared to reptiles, which may use the landscape at smaller scales (Yong et al. 2016).

2. Methods

2.1 Study design

We conducted our study in a 150 km x 120 km area of the wheat-sheep belt of southeastern Australia, in the South West Slopes bioregion of New South Wales (Fig. A1 in the supplementary material). Farms within this region typically have between 3% and 35% native vegetation cover, including remnant temperate box-gum *Eucalyptus* woodland, natural and coppiced regrowth, and restoration plantings (Cunningham et al. 2014). For this investigation, we focused on 189 patches of native vegetation (68 remnant woodland, 61 regrowth woodland, and 60 plantings), which together covered 1437 ha across 43 farms (Table A1 in the supplementary material).

We collected two years of occurrence data for each of our taxonomic groups along a permanent 200 m transect established in each patch. Bird surveys were conducted in spring 2008 and 2011, with each transect visited twice in any given year between sunrise and mid-morning. Each visit involved five-minute point counts at the 0 m, 100 m and 200 m transect points. All birds seen or heard within 50 m of the point, but excluding those flying overhead, were recorded as present. Reptile surveys were conducted in spring 2008 and winter 2011, with each transect visited once between mid-morning and mid-afternoon. Each visit involved a twenty-minute active search of leaf litter, grass tussocks, coarse woody debris, surface rocks, and exfoliating bark, between the 0 m and 200 m transect points. All reptiles seen within 50 m were recorded as present. Visits also involved inspecting arrays of artificial refuges (four wooden railway sleepers, four terracotta roof tiles, and one double stack of 1-m² corrugated steel sheet) placed at the 0 m and 100 m transect points. Arboreal marsupial surveys were conducted in autumn 2008 and winter 2011, with each transect visited once between sunset and midnight. Each visit involved a twenty-minute spotlight survey between the 100 m and 200 m transect points, walking at an average speed of 3 km/h. All species seen or heard were recorded as present.

2.2 Data analysis

We restricted our analysis to species recorded at least twice over the two survey years (Table 1; Table A2 in the supplementary material). This enabled us to exclude vagrant species. This gave 72 species of woodland birds (Silcocks et al. 2005); a subset of 10 species of listed birds (woodland birds listed as threatened in New South Wales in 2016 under the *Threatened Species Conservation Act 1995*; hereafter referred to as a separate taxon for simplicity); three species of arboreal marsupials; and 22 species of reptiles.

For each taxonomic group, our objective was to find complementary sets of patches that met *a priori* representation targets of species occurrences while minimizing the combined area (ha) of the patch set, irrespective of spatial configuration (note that this objective of minimizing the area of vegetation needed to meet representation targets is not intended to identify "unnecessary" vegetation patches, but instead constrain the analyses to best compare surrogate efficacy). To do this, we used Marxan, a decision-support software program that uses a simulated annealing algorithm to solve the minimum set problem (Ball et al. 2009). We created a conservation feature representing patch occurrence of each species in each survey year (two features per species, e.g. for woodland birds we created 144 conservation features in total), following Ikin et al. (2016) and Runge et al. (2016). We set representation targets of 25%, 50%, and 75% occurrence of species in every year (equivalent to 25%, 50%, and 75% of patches where each species occurred). For every combination of taxon and representation target (12 in total), we performed 100 Marxan runs to identify the best patch set. The best patch set was defined as selected patches of vegetation that represented the target of species occurrences in the landscape over the two study years (e.g. 25% representation of woodland bird species occurrences, while ignoring the occurrences of arboreal marsupials and reptiles) for the least combined area. To confirm that patch selection for woodland birds was not sensitive to the subset of listed birds, we re-ran the analyses for woodland birds excluding listed species.

To answer our first question (*Are the vegetation patches selected to meet representation targets for one taxon the same as vegetation patches selected for other taxa?),* we assessed the spatial concordance between the best patch sets for each taxon and representation target. To do this, we calculated Bray-Curtis dissimilarity (adjusted for presence-absence data) between each pair of best patch sets, with low dissimilarity indicating that the spatial locations of the selected patches were similar.

To answer our second question (*Which taxon achieved the best incidental representation of other taxa?*), we assessed how well the best patch sets selected for one taxon represented the occurrences of species in each of the other three taxa. To do this, we calculated the average minimum percent occurrence of each species per taxon that was met over the study period under each best patch set. Incidental representation is a direct measure of surrogate efficacy (Grantham et al. 2010) – the higher the incidental representation of other taxa a particular taxon achieves, the more effective that taxon is as a taxonomic surrogate.

3. Results

Woodland birds were the most species-diverse taxon of the three taxa we studied, every study patch supported at least one woodland bird species, and each species occurred in a median of 10.25 patches (Table 1). In comparison, arboreal marsupials were the least species-diverse taxon, only 51% of patches supported at least one arboreal marsupial species, and each species occurred in a median of 38.00 patches. Consistently across representation targets (25%, 50%, and 75% species occurrences in 2008 and 2011), we found the combined area of the vegetation patches that represented target occurrences of species in the landscape for the least combined area (i.e. the best patch sets) was largest for woodland birds and smallest for arboreal marsupials, although the relative difference in area decreased as representation targets increased from 25% to 75% of species occurrences (Table 1).

We found considerable difference between the spatial locations of the patches in the best patch sets for each taxon and representation target (Fig. 1). For example, the locations of patches in the best patch set to achieve the 25% representation target for arboreal marsupials was up to 76% different from the locations of patches in the best patch sets that met this representation target for other taxa. Even between all woodland birds versus the subset of listed woodland birds, there was up to 55% difference in the locations of patches in the best patch sets selected to meet the same representation target. Similarity between the locations of the patches in the best patch sets was highest between woodland birds and reptiles (as low as 24% difference for the 75% representation target).

In general, we found that the best patch sets selected for one taxon failed to meet representation targets for other taxa (Fig. 2). The best patch sets for woodland birds, as an exception, exceeded targets for the occurrences of the subset of listed woodland birds (Fig. 2a). These best patch sets also came close to meeting target occurrences of the other taxa. For instance, the best patch set to meet the 75% representation target also represented 73% of arboreal marsupials and 69% of reptiles. Listed birds were not driving these patterns as results were similar when this subset of species was removed from the woodland bird taxon (Fig. A2 in the supplementary material). The best patch sets for listed birds, in contrast, did not meet representation targets for other woodland birds, nor representation targets for the other taxa (Fig. 2b). The best patch sets for arboreal marsupials were the worst for representing the occurrences of other taxa; for instance, the best patch set selected to achieve the 75% representation target for arboreal marsupials represented only 27% of woodland birds, 37% of listed birds and 25% of reptiles. (Fig. 2c).

4. Discussion

Woodland birds are a commonly used taxonomic surrogate for other species groups in agricultural landscapes (Eglington et al. 2012; Larsen et al. 2012), but how do they compare with arboreal marsupials and reptiles in conservation planning for biodiversity on farms? We found that the spatial locations of the best sets of vegetation patches selected to meet representation targets for woodland birds were between 24% and 69% different from the locations of the best patch sets selected for other taxa. The locations of the best patch sets selected for reptiles showed a similar amount of spatial concordance to woodland birds, but those selected for arboreal marsupials were between 46% and 76% different from other best patch sets. We found that the best patch sets selected to meet representation targets for woodland birds failed to incidentally meet representation targets for other taxa, although targets for the subset of threatened woodland birds were exceeded. Conservation planning for woodland birds, however, led to higher incidental representation of the other taxa (up to 73% representation under the 75% representation target), compared with conservation planning for arboreal marsupials (up to 27%) and reptiles (up to 62%).

The high species diversity of woodland birds, coupled with the relatively low median number of patches occupied by each species, contributed to their effectiveness as taxonomic surrogates in our study system. In contrast, the species-poor but widely-distributed arboreal marsupial taxon was the least effective taxonomic surrogate. Previous studies have found similar relationships between surrogate efficacy, species diversity and spatial distribution. For example, Beger et al. (2003) demonstrated that marine reserves developed for fish species with heterogeneous distributions were better at representing coral species with homogenous distributions, than vice versa. Similarly, Moritz et al. (2001) found the high diversity and narrow distributions of rainforest invertebrates made them better surrogates compared with less diverse, more broadly distributed taxa. While many studies have assessed vertebrates, those that test the effectiveness of invertebrate taxa as surrogates remain fairly limited (Sauberer et al. 2004), in spite of the ecological importance of many insect groups. We suggest that future research consider how conservation plans for vertebrate taxa, such as birds, represent invertebrates of explicit importance to farm production (e.g. bees), and also if conservation planning for biodiversity on farms can be improved through incorporating non-vertebrate groups.

The broader range of vegetation niches occupied by woodland birds also made them better taxonomic surrogates than arboreal marsupials and reptiles. For example, among the woodland bird taxon were species that foraged in leaf litter (e.g. speckled warbler, *Chthonicola sagittata*), under decorticating bark (e.g. crested shrike-tit, *Falcunculus frontatus*), and in the tree canopy (e.g. striated thornbill, *Acanthiza lineata*); species that fed on invertebrates (e.g. grey fantail, *Rhipidura albiscapa*), nectar (e.g. little lorikeet, *Glossopsitta pusilla*), and seeds (e.g. crested pigeon, *Ocyphaps lophotes*); and species that nested in the understory (e.g. superb fairy wren, *Malurus cyaneus*) and tree cavities (e.g. crimson rosella, *Platycercus elegans*). Thus, the ecological requirements of woodland birds overlapped with those of the arboreal marsupials and reptiles, but the reverse was not true; the arboreal marsupials, in particular, had very low niche diversity (perhaps explaining the high spatial difference between the best patch sets selected for this taxon compared with the other taxa). Our results support previous studies that have found that taxa with similar dependencies on their environment make better surrogates for each other compared with taxa that have different dependencies (Howard et al. 1998; Mortelliti et al. 2008; Heino et al. 2009).

Conservation planning for woodland birds was effective at representing the subset of threatened woodland birds, with representation targets exceeded even when the threatened species were not explicitly considered in the plans. This result was unexpected, as threatened species generally have more restricted distributions, making them more likely to be unrepresented in conservation landscapes (Moore et al. 2003; Grantham et al. 2010). Myšák and Horsák (2014), for example, found that the species richness of red-listed cryptogams and snails were poor surrogates for the species richness of all cryptogams and snails and vice versa. However, consistent with their study, we found that vegetation patches selected to represent threatened woodland birds did not meet targets for other woodland birds, nor arboreal marsupials and reptiles.

We incorporated two years of species occurrence data in our analyses, including from severe drought (2008) and post-drought recovery (2011). This approach accounts for variance in species distributions over time (Ikin et al. 2016; Runge et al. 2016), and thus may improve the robustness of conservation plans to stochastic disturbances (Lourival et al. 2011; Van Teeffelen et al. 2012). However, by only considering species *representation* across the landscape, it is difficult to determine the efficacy of each taxon as surrogates for species *persistence*. It is possible that focusing conservation planning on the population viability of at-risk species, e.g. the group of listed woodland birds, will lead to improved conservation outcomes for other taxa (Williams and Araéjo 2000; Nicholson et al. 2013). Thus, we acknowledge it is possible that assessing the effectiveness of taxonomic surrogates using incidental persistence instead of incidental representation would give as different conclusion as to which taxa was the best surrogate. Future research should consider this question, perhaps using new methods that incorporate both representation and persistence in conservation plans (e.g. Bode et al. 2016).

Our study demonstrates the fundamental trade-offs inherent in single-taxon conservation planning, and taxonomic surrogate approaches (Andelman and Fagan 2000; Wiens et al. 2008). Representation targets for individual taxa were met only through taxon-specific conservation plans, but these plans failed to represent broader farmland biodiversity. Woodland birds proved the best taxonomic surrogates (despite failing to meet targets for arboreal marsupials and reptiles) but the sets of vegetation patches selected to meet representation targets for this taxon were the most spatially extensive. Given that farmland prioritized for biodiversity conservation may compromise production opportunities, spatially extensive conservation plans in these landscapes may have serious economic consequences and may not be feasible or cost-effective to implement or manage (House et al. 2008). In comparison, representation targets for threatened woodland birds could be met with less than 50% of the vegetation area required, but few species from other taxa were also fully represented. It is also important to note that approximately 85% of temperate woodland has been cleared from our study region (Benson 2008), and all remaining vegetation contributes to conservation outcomes (Cunningham et al. 2014). Incidental representation could be improved by incorporating additional species or taxa into the conservation plans (Moore et al. 2003; Larsen et al. 2012), but this approach may increase farmland area prioritized for conservation and thus also increase opportunity costs associated with lost production. These conundrums are not easy to resolve, but require *a priori* value judgements of which aspects of biodiversity on farms should be conserved and what management considerations also should be taken into account.

In conclusion, our study shows that the diverse, easily-studied, and charismatic woodland bird taxon is a more effective taxonomic surrogate than other major farmland vertebrate taxa in this landscape. The present focus on woodland birds in agri-environmental schemes (Guerrero et al. 2012) is thus justified if the conservation goal is to conserve a broad array of biodiversity on farms. However, if particular species or taxonomic groups are considered a conservation priority, then conservation plans explicitly targeting these species or groups will be required to meet conservation goals.

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Table 1. Total richness, total patches occupied, and median and range of patches occupied by each taxonomic group, and the area of the best patch sets selected to meet the 25%, 50% and 75% representation targets of species occurrences.

	Taxon		Species		Area (ha) of best patch set		
	Total richness	Total patches occupied	Median patches occupied	Range patches occupied	25% target	50% target	75% target
Woodland birds	72	189	10.25	1 - 157	274.10	451.10	917.16
Listed birds	10	106	4.25	1 - 43	80.90	187.80	448.76
Arboreal marsupials	3	96	38.00	2 - 59	54.30	168.00	420.96
Reptiles	12	168	5.00	1 - 90	205.40	352.06	719.36

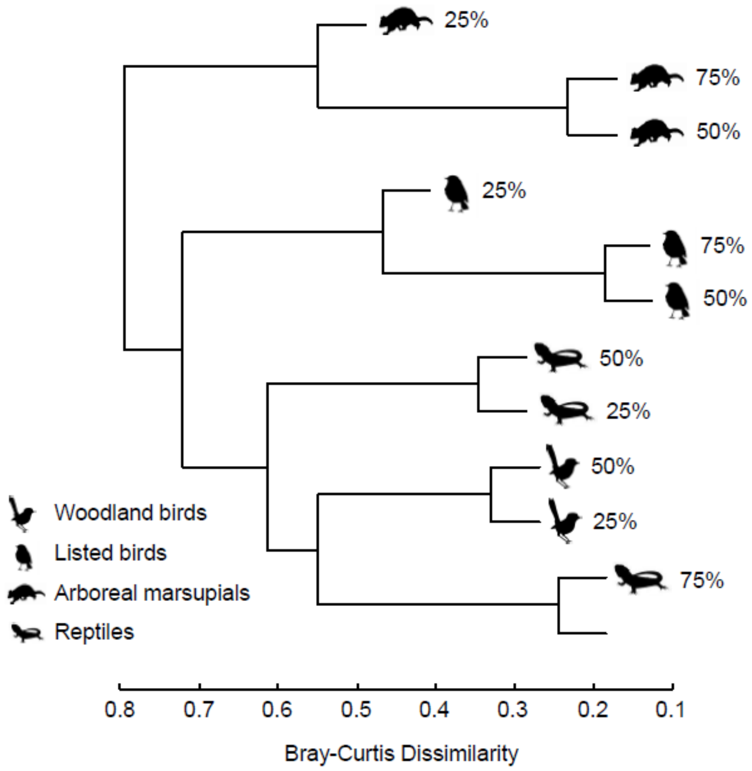

Fig. 1. Spatial dissimilarity of best patch sets selected for 25%, 50% and 75% representation targets of all woodland birds, listed woodland birds, arboreal marsupials and reptiles.

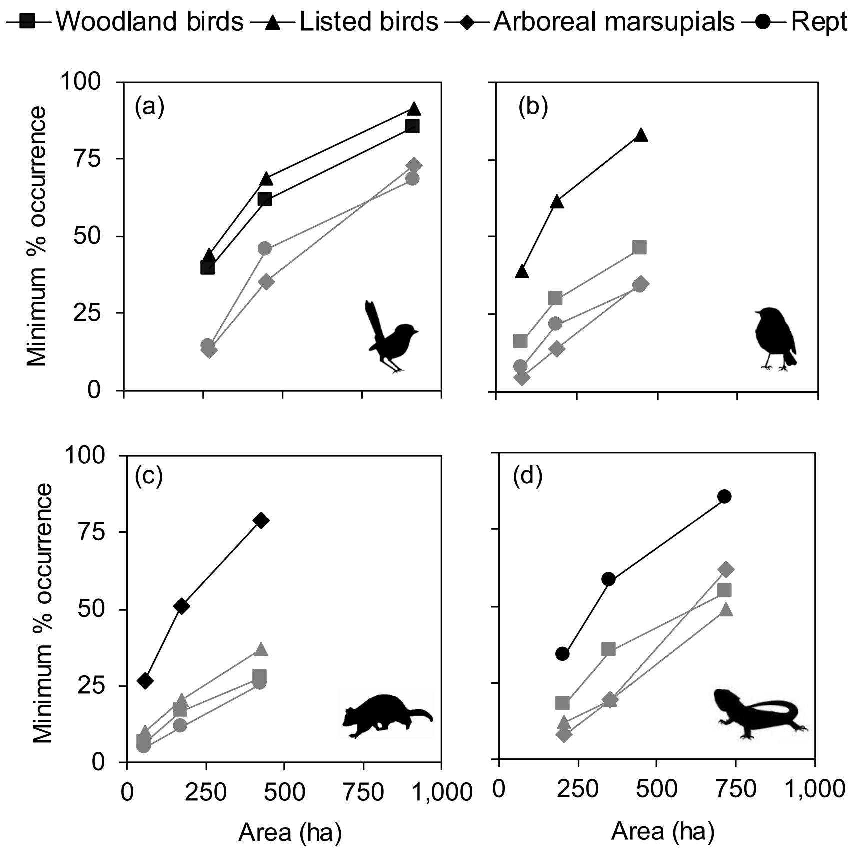

Fig. 2. Minimum occurrence for each taxon achieved by the best patch sets for: (a) woodland birds, (b) listed woodland birds, (c) arboreal marsupials, and (d) reptiles. Points represent 25%, 50% and 75% representation targets. Point color indicates if representation target was met (black) or unmet (grey).

Supplementary material

Effectiveness of woodland birds as taxonomic surrogates in conservation planning for biodiversity on farms

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Table A1. Average (minimum – maximum) site attributes in remnant woodland, regrowth woodland, and planting patches investigated in this study.

Attribute	Remnant woodland	Regrowth woodland	Planting
Patch area (ha)	7.8 (0.8 - 44.7)	10.57 (0.5 - 53.8)	4.24 (0.3 - 60.3)
Canopy height (m)	20.64 (7.67 - 30)	18.4 (8 - 32.5)	10.33 (0.33 - 21.67)
Number of trees	6.3 (0.67 - 52.67)	14.83 (1.33 - 58.33)	29.85 (0 - 203.67)
Number of trees >0.5 m DBH	18.18 (0 - 45.76)	10.42 (0 - 32.24)	1.19 (0 - 11.44)
Number of dead trees/ha	14.49 (0 - 75)	39.89 (0 - 291.67)	17.08 (0 - 100)
Number of strata	2.18 (1.33 - 3.67)	2.5 (1.67 - 4)	2.48 (1.33 - 3.67)
Number of mistletoe/ha	8.33 (0 - 166.67)	8.06 (0 - 158.33)	3.28 (0 - 66.67)
Log density (m3/ha)	198.91 (0 - 1100)	168.99 (0 - 766.67)	32.65 (0 - 283.33)
% Overstory cover	30.87 (0 - 65)	30.04 (6.67 - 80)	14.96 (0 - 86.67)
% Midstory cover	0.24 (0 - 11.67)	0.66 (0 - 10)	7.02 (0 - 71.67)
% Understorey cover	1.11 (0 - 18.33)	1.61 (0 - 15)	1.98 (0 - 11.67)
% Rock cover	4.15 (0 - 41.67)	4.45 (0 - 33.33)	1.24 (0 - 13.33)
% Native tussock cover	11.02 (0 - 62.08)	11.28 (0 - 38.75)	4.49 (0 - 35.42)
% Annual grasses cover	32.49 (0 - 176.25)	25.85 (0 - 74.58)	25.23 (0 - 90.83)
% Broad leaf weeds cover	2.54 (0 - 26.67)	2.42 (0 - 20)	2.38 (0 - 22.08)
% Forbs cover	5.45 (0 - 23.75)	4.52 (0 - 21.25)	3.81 (0 - 30.83)
% Moss and lichen cover	3.25 (0 - 25.67)	3.28 (0 - 24.17)	0.86 (0 - 9.17)
% Bare earth	16.86 (0 - 59.58)	14.06 (0 - 46.67)	16.67 (0 - 68.58)
% Leaf litter	27.56 (0.42 - 69.17)	35.18 (2.08 - 77.5)	37.76 (0.83 - 89.25)

Table A2. List of species in each taxon included in the analyses and the number of patches occupied in each year. Taxonomy follows Christidis & Boles (2008) for woodland birds, Jackson & Groves (2015) for arboreal marsupials, and Wilson & Swan (2013) for reptiles.

Taxon	Scientific name	Common name	# Patches 2008	# Patches 2011
Woodland birds (<u>Listed birds</u>)				
	Acanthiza chrysorrhoa	Yellow-rumped thornbill	38	40
	Acanthiza lineata	Striated thornbill	3	8
	Acanthiza nana	Yellow thornbill	14	27
	Acanthiza reguloides	Buff-rumped thornbill	10	12
	Anthochaera carunculata	Red wattlebird	61	41
	Aphelocephala leucopsis	Southern whiteface	5	0
	Artamus cyanopterus	Dusky woodswallow	25	19
	Artamus personatus	Masked woodswallow	10	9
	Cacomantis pallidus	Pallid cuckoo	2	0
	Chalcites baslis	Horsfield's bronze-cuckoo	7	6
	Chalcites lucidus	Shining bronze-cuckoo	0	3
	<u>*Chthonicola sagittata*</u>	<u>Speckled warbler</u>	1	6
	<u>*Climacteris picumnus*</u>	<u>Brown treecreeper</u>	43	28
	Colluricincla harmonica	Grey shrike-thrush	65	54
	Coracina novaehollandiae	Black-faced cuckoo-shrike	57	61
	Corcorax melanorhamphos	White-winged chough	49	49
	Cormobates leucophaea	White-throated treecreeper	9	9
	Cracticus nigrogularis	Pied butcherbird	24	18
	Cracticus tibicen	Australian magpie	157	141
	Cracticus torquatus	Grey butcherbird	18	19
	Dacelo novaeguineae	Laughing kookaburra	27	28
	Dicaeum hirundinaceum	Mistletoebird	11	12
	Entomyzon cyanotis	Blue-faced honeyeater	11	6
	Eopsaltria australis	Eastern yellow robin	1	1
	Eurystomus orientalis	Dollarbird	2	1
	Falcunculus frontatus	Crested shrike-tit	29	25
	Geopelia placida	Peaceful dove	21	7
	Gerygone albogularis	White-throated gerygone	2	7
	Gerygone fusca	Western gerygone	5	12
	<u>*Glossopsitta pusilla*</u>	<u>Little lorikeet</u>	8	0
	Lalage sueurii	White-winged triller	32	55
	Lichenostomus chrysops	Yellow-faced honeyeater	3	6
	Lichenostomus fuscus	Fuscous honeyeater	5	6
	Lichenostomus penicillatus	White-plumed honeyeater	115	103
	Malurus cyaneus	Superb fairy-wren	41	76
	Manorina melanocephala	Noisy miner	106	82
	<u>*Melanodryas cucullata*</u>	<u>Hooded robin</u>	5	0
	Melithreptus brevirostris	Brown-headed honeyeater	6	9

Taxon	Scientific name	Common name	# Patches	
			2008	2011
	Melithreptus gularis	Black-chinned honeyeater	3	6
	Melithreptus lunatus	White-naped honeyeater	0	2
	Microeca fascinans	Jacky winter	17	13
	Myiagra inquieta	Restless flycatcher	9	18
	Myiagra rubecula	Leaden flycatcher	5	3
	Neochmia temporalis	Red-browed finch	2	2
	Neophema pulchella	Turquoise parrot	0	2
	Ocyphaps lophotes	Crested pigeon	92	53
	Oriolus sagittatus	Olive-backed oriole	3	4
	Pachycephala rufiventris	Rufous whistler	22	57
	Pardalotus punctatus	Spotted pardalote	4	10
	Pardalotus striatus	Striated pardalote	109	97
	Petroica boodang	Scarlet robin	1	1
	Petroica goodenovii	Red-capped robin	11	7
	Phaps chalcoptera	Common bronzewing	19	8
	Philemon citreogularis	Little friarbird	23	12
	Philemon corniculatus	Noisy friarbird	6	10
	Platycercus elegans	Crimson rosella	24	12
	Platycercus eximius	Eastern rosella	147	126
	Polytelis swainsonii	Superb parrot	37	20
	Pomatostomus superciliosus	White-browed babbler	10	4
	Pomatostomus temporalis	Grey-crowned babbler	6	5
	Psephotus haematonotus	Red-rumped parrot	110	85
	Rhipidura albiscapa	Grey fantail	7	31
	Rhipidura leucophrys	Willie wagtail	126	110
	Sericornis frontalis	White-browed scrubwren	3	3
	Smicrornis brevirostris	Weebill	21	40
	Stagonopleura guttata	Diamond firetail	9	19
	Strepera graculina	Pied currawong	5	3
	Struthidea cinerea	Apostlebird	1	1
	Taeniopygia bichenovii	Double-barred finch	1	1
	Taeniopygia guttata	Zebra finch	1	1
	Todiramphus sanctus	Sacred kingfisher	22	16
	Zosterops lateralis	Silvereye	5	9
Arboreal marsupials				
	Petaurus norfolcensis	Squirrel glider	2	7
	Pseudocheirus peregrinus	Common ringtail possum	37	39
	Trichosurus vulpecula	Common brushtail possum	37	59
Reptiles				
	Aprasia parapulchella	Pink-tailed worm lizard	1	28
	Carlia tetradactyla	Southern rainbow skink	32	1
	Chelodina longicollis	Long-necked turtle	0	26
	Christinus marmoratus	Southern marbled gecko	23	49
	Cryptoblepharus pannosus	Ragged snake-eyed skink	52	20

Taxon	Scientific name	Common name	# Patches	
			2008	2011
	Ctenotus spaldingi	Spalding's ctenotus	9	4
	Delma inornata	Olive legless lizard	20	8
	Diplodactylus vittatus	Eastern stone gecko	9	14
	Egernia striolata	Tree crevice-skink	14	5
	Hemiergis talbingoensis	Three-toed skink	6	1
	Lampropholis guichenoti	Garden skink	1	1
	Lerista bougainvillii	Bougainville's skink	2	4
	Lerista timida	Three-toed lerista	4	2
	Menetia greyii	Grey's skink	3	0
	Morelia spilota ssp. *metcalfei*	Inland carpet python	0	90
	Morethia boulengeri	Boulenger's skink	87	15
	Pogona barbata	Eastern bearded dragon	3	1
	Pseudechis porphyriacus	Red-bellied black snake	0	7
	Pseudonaja textilis	Eastern brown snake	3	0
	Tiliqua scincoides ssp. *scincoides*	Eastern blue-tongue	3	1
	Underwoodisaurus milii	Barking gecko	1	3
	Varanus varius	Lace monitor	2	0

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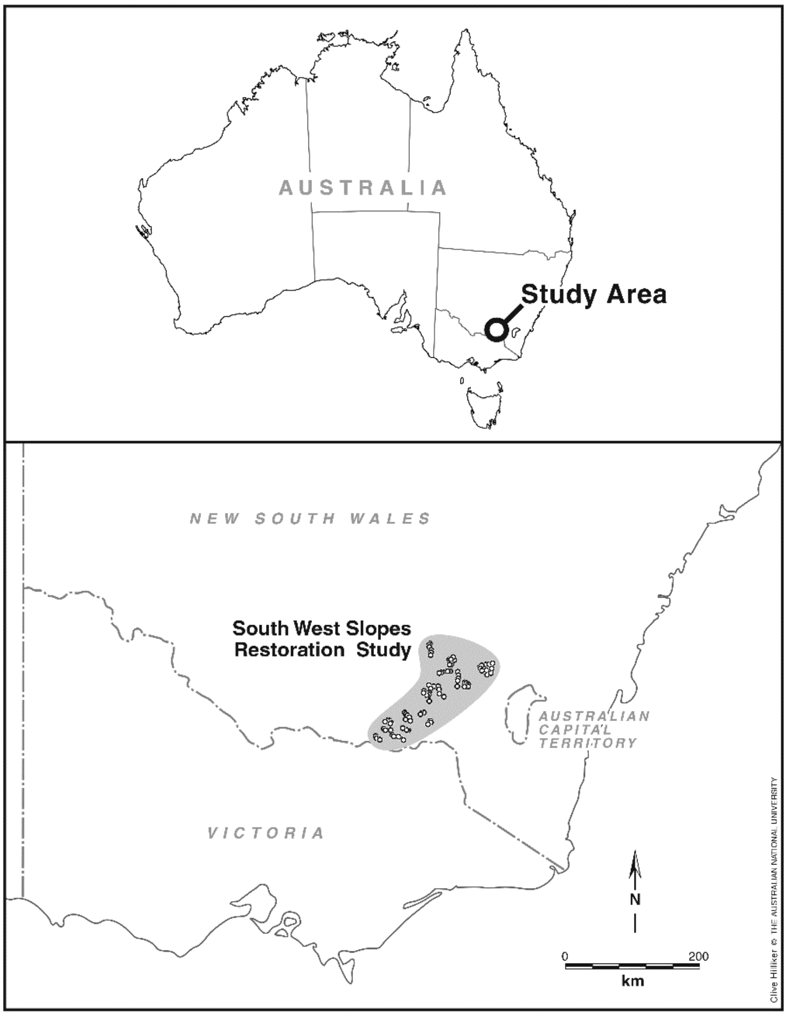

Figure A1. Map of the study area in the South West Slopes, Australia.

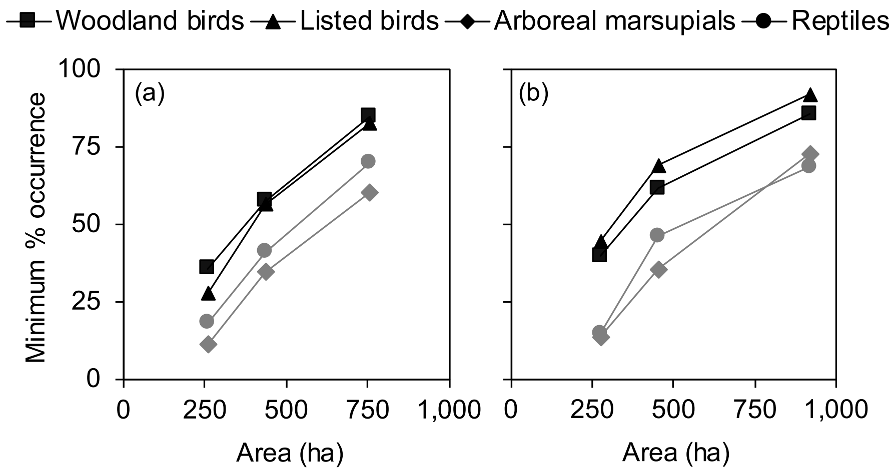

Figure A2. Minimum occurrence for each taxon achieved by the best patch sets for: (a) woodland birds including subset of listed birds, and (b woodland birds excluding subset of listed birds. Points represent 25%, 50% and 75% representation targets. Point color indicates if representation target was met (black) or unmet (grey).